MATERIALS BUREAU

TECHNICAL REPORT 92-3

IN-SERVICE PERFORMANCE OF EPOXY-COATED STEEL REINFORCEMENT IN BRIDGE DECKS

JUNE 1992

M.A.P. CODE 7.42-6-92-3

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
MARIO M. CUOMO, Governor
FRANKLIN E. WHITE, Commissioner

92-1 Wisconsin Dept. of Transportation
DIVISION OF HIGHWAYS AND
TRANSPORTATION SERVICES
Materials Research Section

RESEARCH LITERATURE
EL7R 1186

Title In-Service Performance of Epoxy-Coated Steel Reinforcement in Bridge Decks	File Location 4.1.05 Pavement Performa. Reinforced Concrete Date Jun 1992
Agency New York DOT	Report No. Technical 92-2
Author(s) Perregaux,Brewster	Key Words Condition Survey, Corrosion, epoxy-coated steel, bridge decks

CIRCULATION/REVIEW

Department	Name	Date	Comments

TECHNICAL REPORT 92-3

IN-SERVICE PERFORMANCE OF EPOXY-COATED STEEL REINFORCEMENT IN BRIDGE DECKS

FINAL REPORT

Prepared by

Gerald R. Perregaux
David R. Brewster

June, 1992

MATERIALS BUREAU
WAYNE J. BRULE, DIRECTOR

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
1220 WASHINGTON AVENUE, ALBANY, NY 12232

M.A.P. CODE 7.42-6-92-3

CONTENTS

INTRODUCTION 1

PURPOSE 1

BRIDGE SAMPLE 1

EVALUATION METHODS 3

RESULTS 3

1. Field Phase 3

2. Laboratory Phase 3

a. Corrosion 6

b. Concrete Core Cracks 7

c. Concrete Cover Thickness 8

d. pH Level and Chloride Levels 8

e. Coating Thickness 9

DISCUSSION 9

SUMMARY 10

INTRODUCTION

One of the earliest uses of epoxy coating on reinforcing steel in concrete bridge decks in New York State was in a structure built in 1975 in the Village of Arcade. The coating was Flintflex, which is no longer produced. Numerous transverse cracks, believed due to drying shrinkage, developed within the first 3 years. Shallow concrete cover over the reinforcing steel, as little as 7/8 in. in places, may have contributed to the cracking. Delaminations were first observed in 1989, and were attributed to corroded transverse bars in the top mat. Spalls and delaminations have increased in number and size. According to a survey in 1991, the total area of delaminations and spalls involves about 5 percent of the deck.

The Arcade experience was considered an isolated incident, attributed largely to either shallow concrete cover or the Flintflex coating, which FHWA later found in their experiments to be unacceptable. No other bridge deck of similar construction in the state has developed distress to the extent or severity experienced at the Arcade bridge. Consequently, bridge decks with epoxy-coated steel reinforcement are assumed to be performing well. Reports of early and severe corrosion of epoxy-coated rebars in the Florida Keys Bridges, however, raised new concerns. The Department decided to take a closer look at bridge deck performance to determine if epoxy-coated steel reinforcement was corroding prematurely.

This report presents the results of an investigation conducted in 1990 by the Materials Bureau on a small sample of in-service bridge decks containing epoxy-coated rebars.

PURPOSE

The purpose of this study is to assess corrosion protection provided by epoxy coatings on steel reinforcement in older bridge decks. The Department implemented a policy for use of epoxy-coated bars in the top mat of steel reinforcement in bridge decks in October 1976.

BRIDGE SAMPLE

A biased survey sample of 14 older in-service bridges reported to have deck surface distress was selected to represent a "worst case" for evaluation. Bridge ages and deck wearing surface condition ratings were found in the Department's Bridge Inventory and Inspection System. A sort of data in this system produced a list of candidate bridges to consider. This list was further refined with more detailed construction data available in regional offices to arrive at the survey sample of 14 bridges.

The bridges in the sample ranged in age from 7 to 12 years. Decks with spalls could not be found. Distress was limited to transverse cracks of varying severity, believed caused by shrinkage during construction. Table 1 gives particulars on each bridge.

Table 1. BRIDGES SURVEYED

ID #	Region	Route	City Town Village	Location	Year Built	Year Reconstructed	Age	Length	# of Spans	Average Annual Daily Traffic
1070700	1	88I	Duanesburg	.4 Mi. E. Jct. Rts. 20 & I88	1981	-	9	298	2	10,000
107086C	1	787I	Troy	City of Troy	1981	-	9	1093	7	54,900
1052020	2	365	Barneveld	06 Mi. S. Jct. Rts. 365 & 12	1931	1979	11	62	1	2,800
1069800	2	Ramp	Rome	W. of Jct. Rome Art. & Rte. 233	1980	-	10	100	1	800
1040070	3	200	Harford	0.1 Mi. E. Jct. Rts. 38 & 200	1934	1979	11	84	1	400
1040080	3	200	Harford	0.1 Mi. SE Jct. Rts. 200 & 221	1924	1979	11	38	1	400
3312170	3	23	Cincinnatus	1.4 Mi. NE Jct. Rts. 26 & 41	1981	-	9	187	2	900
1071111	4	390I	Avon	2.4 Mi. N. Jct. Rts. 390I & 20A	1980	-	10	863	4	11,600
1000530	7	3	Le Ray	0.4 Mi. E. Jct. Rts. 3 & 342	1948	1983	7	167	2	10,400
1000540	7	3	Rutland	0.5 Mi. E. Jct. Rts. 3 & 342	1948	1983	7	224	3	8,600
1017600	9	23	Davenport	0.1 Mi. SW Davenport Centr.	1979	-	11	218	2	5,300
1027060	9	55	Neversink	Jct. Rte. 55 & Neversink R	1953	1978	12	283	6	2,300
1071010	9	Main	Oneonta	City of Oneonta	1979	-	11	341	3	5,900
1072300	10	Conn	Islip	0.4 Mi. E. Insect. Rt. 27 & HSP	1983	-	7	269	3	12,000

Three different brands of epoxy coating had been used to coat the steel reinforcement: Scotchkote 213 and Scotchkote 214 manufactured by the 3M Company, and the Armstrong Product Company's Epoxiplate R349. Scotchkote 213 and 214 are now available and approved for use in New York State, but the Armstrong epoxy is no longer being manufactured.

EVALUATION METHODS

The evaluation included field and laboratory phases.

A field evaluation consisting of visual, chain drag, and pachometer surveys was conducted on each of the 14 bridges in the sample. One travel lane of each span was surveyed visually to assess condition of the deck wearing surface, i.e., cracks, spalls, and patches. The chain drag survey was used to detect delaminations. The pachometer survey measured concrete thickness over the steel reinforcement, but was discontinued after the first few bridges. Differences between pachometer measurements and measured thicknesses of concrete cover from cores varied from 1/4 to 2-1/2 in., inconsistencies believed due to sensitivity of the pachometer to temperature changes.

Fifty-four concrete decks cores were obtained from 26 of the 34 spans listed in Table 1 for analysis at the Materials Bureau laboratory. They were generally taken in wheelpaths at locations of cracks, delaminations, and patches, as well as in areas of no surface distress for reference. Cores were drilled to a depth below the top steel reinforcement to include the bar.

In the laboratory phase, cores were evaluated to determine concrete properties and epoxy coating performance. Each was measured to record actual thickness of concrete over the reinforcement. Presence, width, and depth of cracks were noted. Concrete powder next to the steel reinforcement was sampled to determine pH and chloride levels. Epoxy coating thickness was measured, and its performance visually assessed. The extent of corrosion, if present, was noted.

RESULTS

1. Field Phase

Transverse cracks were found on all but one of the 26 spans evaluated, normally less than 1/16 in. wide and extending over the width of the travel lane. Most spans contained five or more transverse cracks. No specific pattern regarding their spacing was observed, but most were located near the center of the span.

No spalls were found in any of the bridge decks surveyed. Only one delamination was found, in a deck that was 9 years old. The area of delamination measured 2 sq ft (1 x 2 ft). A core taken through the delamination indicated that the thickness of the concrete over the steel reinforcement was 2-3/8 in. The delamination occurred 7/8 in. below the deck surface, indicating that the delamination was unrelated to bar corrosion in the sample core.

2. Laboratory Phase

Table 2 summarizes information on the 54 cores evaluated by the Materials Bureau, obtained from several sources: the Bridge Inventory and Inspection System data base, the field survey, and laboratory analyses. Forty cores had steel reinforcement coated with the 3M Scotchkote 213 epoxy, six with 3M Scotchkote 214, and eight with Armstrong R349.

Table 2. EVALUATION OF 54 FIELD CORES

Bridge			Concrete Core					Epoxy Coating		
ID #	Age	Span #	Core #	Condition (1)	Cover (inches)	pH (2)	Cl (ppm) (2)	Type	Thickness (mils)	Extent of Corrosion (3)
1000530	7	1	2	D	4.000	12.0	0	3M/214	7.00	R
1000530	7	1	1	D	2.500	12.0	1070	3M/214	7.90	R
1000540	7	1	2	N	2.250	12.1	0	3M/214	6.50	N
1017600	11	1	2	N	2.000	12.0	392	3M/213	5.75	N
1017600	11	1	3	D	2.250	11.9	428	3M/213	9.25	N
1017600	11	1	1	S	2.750	12.0	71	3M/213	8.00	N
1017600	11	2	2	N	2.750	11.8	36	3M/213	8.50	N
1017600	11	2	1	N	3.250	11.9	0	3M/213	8.75	N
1017600	11	2	3	N	3.250	11.9	0	3M/213	8.50	N
1027060	12	2	1	N	3.250	11.8	928	3M/213	13.75	N
1027060	12	1	2	D	3.000	11.8	785	3M/213	12.00	R
1027060	12	1	3	N	2.375	11.9	1606	3M/213	7.50	N
1027060	12	1	1	D	3.000	11.7	1641	3M/213	9.00	R
1027060	12	3	3	S	3.000	11.9	1106	3M/213	7.25	N
1027060	12	3	2	D	3.000	11.9	1142	3M/213	8.25	R
1027060	12	3	1	N	3.000	11.9	535	3M/213	5.00	N
1027060	12	2	3	D	2.375	11.8	2854	3M/213	10.50	B
1027060	12	2	2	D	3.125	11.9	1142	3M/213	8.75	N
1040070	11	1	1	D	2.750	12.1	1499	3M/213	9.50	R
1040070	11	1	3	N	2.000	11.9	214	3M/213	11.25	N
1040070	11	1	2	S	2.250	11.9	1855	3M/213	7.00	R
1040080	11	1	1	N	1.625	11.9	3211	3M/213	13.00	N
1040080	11	1	2	N	2.375	12.0	2426	3M/213	11.25	N
1052020	11	1	1	N	2.000	11.9	3068	3M/213	8.75	N
1052020	11	1	2	D	2.125	12.0	1213	3M/213	8.75	N
1069800	10	1	2	N	2.000	12.1	214	A/R349	7.75	N
1069800	10	1	1	S	2.000	12.0	103	A/R349	9.25	N
1070700	9	1	1	D	3.000	12.0	2605	3M/213	10.25	B
1070700	9	2	1	D	2.250	12.1	1820	3M/213	12.00	R
107086C	9	1	1	N	2.875	11.8	392	A/R349	8.49	N
107086C	9	2	1	D	3.250	11.9	821	A/R349	7.65	R

Table 2. (continued)

Bridge			Concrete Core					Epoxy Coating		
ID #	Age	Span #	Core #	Condition (1)	Cover (inches)	pH (2)	Cl (ppm) (2)	Type	Thickness (mils)	Extent of Corrosion (3)
1071010	11	3	2	D	4.250	11.9	285	3M/213	8.50	R
1071010	11	3	3	N	3.750	11.9	214	3M/213	8.50	N
1071010	11	3	1	D	4.250	12.0	1249	3M/213	11.50	R
1071010	11	2	1	N	3.375	12.0	71	3M/213	12.25	N
1071010	11	1	1	D	4.250	12.0	999	3M/213	12.50	B
1071010	11	1	2	N	4.000	12.0	107	3M/213	9.75	N
1071010	11	2	2	S	4.250	12.0	214	3M/213	10.75	N
1071111	10	3	3	D	3.000	12.2	1641	3M/213	7.30	R
1071111	10	3	1	N	2.250	12.0	392	3M/213	7.00	N
1071111	10	2	3	S	3.500	12.1	1427	3M/213	7.70	R
1071111	10	1	1	D	3.250	12.0	1891	3M/213	8.80	R
1071111	10	3	2	S	3.250	12.0	607	3M/213	7.40	N
1071111	10	4	3	S	3.000	12.1	1570	3M/213	8.90	N
1071111	10	4	1	N	2.625	12.0	143	3M/213	8.90	N
1071111	10	4	2	S	3.375	12.1	1284	3M/213	7.60	N
1071111	10	1	2	D	3.125	12.0	2391	3M/213	7.90	R
1072300	7	1	2	D	3.375	12.0	963	3M/214	5.80	R
1072300	7	1	1	N	2.875	11.8	0	3M/214	7.30	N
1072300	7	2	4	N	3.250	12.1	0	3M/214	6.90	N
3312170	9	2	2	N	2.375	11.9	535	A/R349	9.75	N
3312170	9	1	1	S	2.000	12.0	428	A/R349	11.25	N
3312170	9	1	2	N	2.375	12.0	571	A/R349	11.25	N
3312170	9	2	1	N	1.750	12.0	1784	A/R349	10.75	N
			Minimum		1.625				5.00	
			Maximum		4.250				13.75	
			Average		2.873				8.99	

Notes: (1) Core Condition: "N" - no crack; "S" - shallow crack (short of rebar level); "D" - deep crack (extending to rebar)

(2) pH & Cl: samples taken in the immediate area of coated rebars

(3) Corrosion: "N" - negligible corrosion; "R" - rib corrosion (limited to small areas and raised deformations; "B" - bar corrosion (more extensive - both raised deformations and body of bar affected)

a. Corrosion

Reinforcement removed from the 54 cores for the most part showed very minor corrosion, limited to small areas. It normally appeared as pinpoints of rust, or on the raised bar deformations (ribs), or in small areas (<1/4 x 1/4 in.) on the body of the bar. Corroded areas were normally located on the top or side surfaces of bars directly exposed to cracks in the deck. Severity of corrosion on rusted areas was superficial, or can be generally described as light rusting. No bar showed complete coating deterioration, and none had pits or loss of steel section. There was no undercutting of the epoxy coating surrounding a corroded area.

The following scale was used to describe the extent (not severity) of corrosion on the epoxy-coated steel reinforcement:

1. **Negligible Corrosion**. No corrosion or no spot(s) of corrosion on the body of the bar greater than 1/4 x 1/4 in.

2. **Rib Corrosion**. Corrosion limited to the raised deformations (ribs); spot(s) of corrosion on the body of the bar less than 1/4 x 1/4 in.

3. **Bar Corrosion**. One or more corroded areas on the body of the bar greater than 1/4 x 1/4 in., in addition to corrosion on the raised deformations (ribs).

Although this scale is arbitrary, it is based on the Department's Standard Specification definition for distinguishing between major and minor coating damage. Defects or breaks in the coating 1/4 x 1/4 in. or larger are considered major damage, requiring field repairs with patching material. More than five major damaged areas in any 10-ft length of bar is cause for rejection. Also, the average number of unrepaired minor damaged areas cannot exceed six per foot on any individual bar.

Using this scale, extent of rebar corrosion removed from the 54 concrete core sample was evaluated subjectively:

1. 35 bars (65%) had negligible corrosion,

2. 16 bars (30%) had only rib corrosion, and

3. 3 bars (5%) had bar corrosion.

These last three were obtained from different bridges, from cores taken from decks with surface defects. Each had a crack extending to the steel reinforcement, providing a direct conduit for chloride-contaminated water. In addition, one core was from a span with a delamination, and another through a patched area. All the bars were coated with 3M Scotchkote 213 epoxy powder.

b. Concrete Core Cracks

The 54 cores were examined for cracks and other defects in the concrete that would effectively reduce the time for chlorides to reach the steel and create a corrosive environment. Three cracking categories were defined:

1. **No Crack.** None was observed in the core.

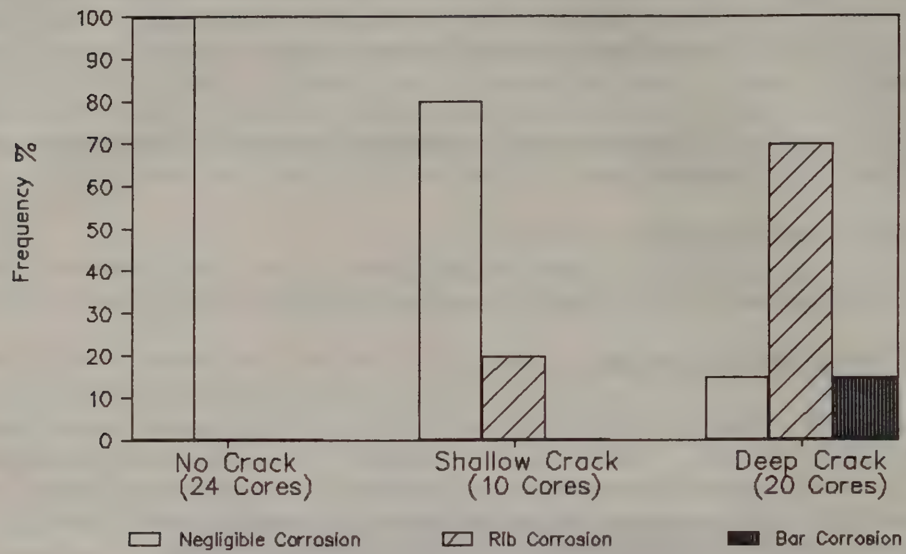
2. **Shallow Crack.** One existed on the surface but did not extend to the depth of the reinforcement.

3. **Deep Crack.** A surface crack extended to the steel or beyond.

Visual inspection found 24 cores (44%) had no cracks, 10 (19%) had a shallow crack, and 20 cores (37%) had a deep crack.

Figure 1 shows the apparent influence of cracks on corrosion. No bars from the 24 cores with no cracks had significant corrosion. Of the 10 cores with shallow cracks, 80% had negligible corrosion and 20% had rib corrosion. No cores in this group had bar corrosion. Of the 20 cores with deep cracks, 15% had negligible corrosion, 70% rib corrosion, and the remaining 15% bar corrosion. Figure 1 suggests that corrosion is more likely to occur and be more extensive if the concrete cover protecting the steel is cracked.

FIGURE 1. CORROSION ACTIVITY ON EPOXY-COATED REBARS IS GREATER WITH DECK CRACK SEVERITY



c. Concrete Cover Thickness

All decks in this study were constructed under specifications requiring 2 1/2 ± 1/2 in. of Class E concrete over epoxy-coated steel reinforcement in the top mat. Department research estimates that with this 2-1/2 in. target depth of cover, a minimum cover depth of 2 will be obtained 92% of the time (Research Report 67).

Measured concrete cover thickness of the 54 cores averaged 2.873 in., and ranged from a minimum of 1.625 in. to a maximum of 4.250 in. Fifty-two (96%) of the 54 cores were in compliance with the specification requiring a 2 in. minimum cover. Based on this sample, construction practices governing concrete cover thickness meet the specifications.

d. pH Level and Chloride Levels

The high alkalinity of fresh concrete causes a thin oxide layer to form on the steel (exposed areas on coated rebars), acting as a partial barrier to further corrosion. Steel in this state is considered passivated. Over time, after repeated applications of deicing salts, chlorides eventually reach the top rebar level. Chloride ions directly react with the steel surface and break down the thin oxide layer protecting the rebar. When the pH at the rebar surface is reduced to below 10, the steel is no longer considered passivated. In the presence of moisture and oxygen, corrosion will occur at a very rapid rate.

The amount of chloride steel in concrete can tolerate before corrosion begins is not a unique number. Numerous variables involving materials and exposure conditions affect the chloride concentration that results in the loss of steel passivity. When other conditions are right, chloride values greater than 330 ppm (0.033%) on a concrete weight basis, or 1.3 lb of chloride/cu yd, have been associated with steel corrosion. This is considered the threshold value by the Department and FHWA.

Samples of the cement paste for laboratory determination of chloride and pH levels were obtained from each core at the depth of the rebar by drilling parallel to the rebar, about 1 in. from it. Average chloride level for the 54 cores in this study was 962 ppm, which is almost triple the threshold value of 330 ppm necessary to provide a corrosive environment. pH levels in the 54 cores ranged from 11.7 to 12.2, and averaged 12.0. These levels are considerably higher than the critical range, indicating that passivity has been destroyed. Lower pH levels might have been obtained if samples had been taken directly on top of the rebar.

No correlation was found between chloride level and severity of core cracking, or for pH level and crack severity.

e. Coating Thickness

The specification requirement for thickness of the epoxy coating on steel reinforcement is 5 to 9 mils. Coating thickness was measured in at least four locations on each rebar. One or more of these measurements was over a raised deformation. Values reported in Table 2 represent averages of the individual measurements taken for each rebar. Average coating thickness on the sample of 54 bars was 8.99 mils and varied from 5.00 minimum to 13.75 maximum. All samples complied with specifications for minimum coating thickness, but exceeded the maximum thickness on 20 occasions (37% of the time).

DISCUSSION

In this study, corrosion of the epoxy-coated steel reinforcement was not significant. Protection provided by epoxy coatings appeared satisfactory. This conclusion is based primarily on the fact that undercutting of the coating, pitting of the steel, or section loss of the bar were not found. On the other hand, some corrosion was found on a third of the rebars sampled, a few with only 7 years service. How these rebars will perform in the future is unknown.

At this time long-term corrosion protection provided by epoxy coatings on rebars cannot be quantified by New York State field experience. Normal service lives of bridge decks incorporating epoxy-coated steel reinforcement have yet to be reached. Based on this survey, bridge decks in the sample continue to be damage-free after as long as 12 years of service. This is of no real significance since the Engineering Research and Development Bureau projected a damage-free deck life of 16 years for plain-bar decks with 2.25 in. of concrete cover (Special Report 92). No such projections have been made for decks with epoxy-

coated steel reinforcement. For the time being, estimates of corrosion protection provided by epoxy coatings on rebars will have to be based on results of laboratory tests. This survey provides only a glimpse of coating performance at one point in service lives of a few selected rebars.

The extent of corrosion in the study sample is judged minor and of little concern at this time. Corrosion generally appeared as light rusting and was restricted to small areas. The number and size of these areas (e.g., 1/4 x 1/4 in.), in some cases might have warranted field repairs in accord with construction specifications. How and when these breaks in the epoxy coating occurred, and why field repairs were not performed if needed, are questions that cannot be answered. Perhaps some of the corrosion observed could have been prevented with better quality assurance procedures or practices.

Transverse cracking in bridge decks has never been directly related in the Department's previous research to corrosion activity on steel reinforcement (other than localized). In the Engineering Research and Development Bureau's Special Report 11, transverse cracking was not found to affect deck life. Perhaps this conclusion needs to be reexamined, for presence of transverse cracks appeared in this study to be directly related to the amount of corrosion found on rebars.

Most previous research documenting the merits of epoxy-coated steel reinforcement involved uncracked slabs. A transverse crack in the deck extending down to the level of reinforcement, however, provides a different environment for the coating. Even though deck cracks are usually narrow (1/16 in.), they provide a direct path for chloride-laden water and atmospheric carbon dioxide to reach epoxy-coated steel reinforcement. Presence of other contaminants and exposure to wetting and drying cycles are likely to provide a harsher environment than is found in uncracked slabs. How this environment affects integrity of the epoxy coating, which functions as a barrier, is unknown at this time. Time-to-corrosion estimates developed for intact concrete cover may not be applicable under these conditions. Significance of transverse cracks for expected damage-free life of decks with epoxy-coated bars warrants further study.

SUMMARY

To assess the corrosion protection provided by epoxy coatings on steel reinforcement in bridge decks, a sample of 14 bridges (26 spans) was selected for field survey and laboratory analysis of deck cores. To provide a worst-case sample, bridges known to have deck surface distress were intentionally selected, when possible, over ones in better condition. They ranged in age from 7 to 12 years. Steel reinforcement was protected with one of three different kinds of epoxy coating: 3M 213 (74% of the cores), 3M 214 (11%), or Armstrong R349 (15%). According to the 1989 Bridge Inventory and Inspection System, the Department had constructed 698 bridges (1606 spans) with epoxy- coated steel reinforcement in the top mat. The policy to use epoxy coated bars with 2 in. minimum thick, Class E concrete cover was implemented in October 1976.

The field survey of bridges in the study sample indicated that 25 of the 26 spans evaluated had transverse cracks in their decks. Only one delamination was found, apparently unrelated to rebar corrosion. There were no spalls. A total of 54 cores, taken for laboratory analyses by the Materials Bureau, are the subject of this report.

Based on the Materials Bureau's evaluation of epoxy-coated rebars with 7 to 12 years service, corrosion is not a problem at this time. Corrosion of some significance, though not severe, was found on only 3 (5%) of the 54 bars, all coated with 3M 213 epoxy powder. No bar showed complete coating deterioration or pitting or loss of steel section. There was no undercutting of epoxy coating surrounding a corroded area.

This survey showed no strong relationship between corrosion and thickness of concrete cover, pH, chloride level, epoxy coating thickness, or deck age. While all are factors known to have some effect on corrosion, when singled out for analysis they show no independent relationship with extent of corrosion as characterized in this report. The survey found both depth of concrete cover and thickness of epoxy coating to be in conformance with construction specifications.

The survey did find greater corrosion activity on epoxy-coated steel reinforcement at locations where the bridge deck surface was cracked. The protective epoxy coating appeared to not perform as well under these conditions. The significance of cracks in the bridge deck, and their relation to corrosion on epoxy-coated steel reinforcement, warrant more study.

The field survey of bridges in the study sample indicated that 25% of the spans evaluated had transverse cracks in their decks. Any [illegible] deterioration was found apparently unrelated to rebar corrosion. There were no spalls. A total of 54 cores, taken for laboratory analyses by the Materials Bureau, are the subject of this report.

Based on the Materials Bureau's examination of epoxy-coated rebars with 7 to 12 years service, corrosion is not a problem at this time. Corrosion of some significance, though not severe, was found on only 9 (17%) of the bars, all coated with 3M 213 epoxy powder. None showed complete coating delamination or pitting corrosion [illegible]. There was no deterioration of epoxy coating surrounding a corroded area.

This survey showed no strong relationship between corrosion and thickness of concrete cover, pH, chloride level, epoxy coating thickness, or deck age, while all are factors known to have effects on corrosion, when single-factor analysis [illegible] they show [illegible] variations [illegible] characterized in this report [illegible] and [illegible] of cover and thickness of epoxy coating [illegible] in accordance with specifications.

The survey did find greater corrosion activity on epoxy-coated steel reinforcement at locations where the bridge deck surface was cracked. The protective epoxy coating appears not to perform as well under these conditions. The significance of cracks in the bridge deck, and their relation to corrosion of epoxy-coated steel reinforcement, warrants more study.